Instruction-based response activation depends on task preparation

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Abstract

An increasing number of studies demonstrate that a response in one task can be activated automatically on the basis of merely instructed S-R mappings belonging to another task. Such instruction-based response activations are considered as evidence for the formation of S-R associations on the basis of the S-R mappings for an upcoming but not yet executed task. A crucial but somewhat neglected assumption is that instructed S-R associations are formed only under conditions imposing a sufficient degree of task preparation. Accordingly, the present study investigated the relation between task preparation and the instruction-based task-rule congruency effect, which is an index of response activation on the basis of instructions. Two experiments demonstrate that merely instructed S-R mappings of a particular task only elicit instruction-based response activations when that task is prepared for to a sufficient degree. Implications for the representation of instructed S-R mappings in working memory are discussed.

In analogy to practiced S-R associations (Sudevan & Taylor, 1987), Stimulus-Response (S-R) associations that are only formed on the basis of instructed S-R mappings can also lead to automatic response activations when being task irrelevant (De Houwer, Beckers, Vandorpe, & Custers, 2005; Liefooghe, Wenke, & Houwer, 2012; Wenke, Gashler, & Frensch, 2007). Both types of associations are however represented by different working-memory components. Working memory supposedly exists of activated long term memory (ALTM) and the direct-access region (DA; Oberauer, 2009). ALTM encompasses activated representations of existent information. DA consists of a restricted subset of highly activated representations within ALTM. While DA is capacity limited, ALTM is (virtually) not. Instructed S-R associations are assumed to be represented in DA in the form of a temporal binding (Hommel, 2009) between preexisting representations in ALTM, such as stimulus and response codes (Liefooghe et al., 2012; Meiran, Cole, & Baver, 2012). In contrast, practiced S-R associations would be completely represented in ALTM, because these associations have been pre-established through practice (e.g., Meiran & Kessler, 2008). This distinction is supported by studies demonstrating that instruction-based response activations can be eliminated by a concurrent working memory load (Meiran & Cohen-Kdoshay, 2012), while response activation on the basis of practiced S-R associations cannot (Kessler & Meiran, 2010). Furthermore, response activation on the basis of practiced S-R associations is not affected by task preparation (Yamagushi & Proctor, 2011), which suggests that such activation is related to the episodic retrieval of S-R associations from ALTM and is independent of top-down processes, such as maintenance in the DA.

In contrast, instruction-based response activations are assumed to be only present when the instructed task is prepared (Liefooghe et al., 2012; Meiran et al., 2012). Liefooghe et al. (2012) used the instruction-based task-rule congruency effect (IB-TRCE) for measuring instruction-based response activations. Two tasks were used: an inducer task and a diagnostic task (Figure 1). Each run started with the presentation of a pair of S-R mappings of the inducer task, which indicated the response to the identity of a probe stimulus that was presented later on. Between the onset of the S-R mappings and the onset of the probe, several trials of the diagnostic task were presented. Both tasks shared stimuli and responses, but now participants only responded to the orientation of the stimuli (if upright press left; if *italic*, press right). The IB-TRCE refers to the finding that RTs in the diagnostic task were faster when the response in the diagnostic task corresponded to the S-R mappings of the inducer task (an upright P requiring a left key-press), than when it did not (an italic *P* requiring a left key-press). The IB-TRCE was however only present when participants intended to apply one of the instructed S-R mappings. When the instructed S-R mappings had to be maintained for future recall no IB-TRCE was observed. Liefooghe et al. (2012) proposed that only when participants have to apply the S-R mappings of the inducer task, this task is prepared for by making a compound of the relevant features needed for its execution, which elicits an IB-TRCE when being irrelevant. Although task preparation was not directly manipulated, the study of Liefooghe et al. (2012) thus offers a first indication that instruction-based response activation and task preparation are related.

Wenke, Gaschler, Nattkemper, and Frensch (2009) equally suggested that instruction-based response activation depends on task preparation. They used an inducer task, in which only one trial of a diagnostic task was embedded. In this diagnostic task, two adjacent letters with different font-sizes were presented and participants judged if the bigger letter appeared on the left or on the right side of the screen-centre by pressing a central response key once or twice. RTs in the diagnostic task were slower when the letter position on the screen was incompatible with the response locations assigned to these letters in the instructed S-R mappings than when the left-right positions were compatible with the response locations of the instructed S-R mappings. Based on the assumption that the instructed response-location codes of the inducer task and the stimulus-location codes of the diagnostic task are represented in a common medium (Hommel, 2009), Wenke et al. (2009) concluded that this compatibility effect was related to instruction-based response activations. Interestingly, this effect was not present when no-go cues frequently signaled that the inducer task would not proceed. The frequent presentation of no-go cues may thus have discouraged participants to prepare for the inducer task, which again suggests that instruction-based response activation and task preparation are related. However, Meiran et al. (2012) argued that the compatibility effect observed by Wenke et al. (2007; 2009) does not reflect instruction-based response activations, but the (mis)match between the left-right display of the letters in the diagnostic task and the S-R mappings of the inducer task.

Although the studies of Wenke et al. (2009) and Liefooghe et al. (2012) suggest that instruction-based response activation depends on task preparation, their interpretation may be open for discussion. Accordingly, the present study goes beyond these studies by offering a more unequivocal demonstration that instruction-based response activation depends on task preparation. To this end, we manipulated the necessity to prepare for the inducer task, while measuring whether this influenced the presence of IB-TRCE in the diagnostic task.

Experiment 1

On each run of Experiment 1 (Figure 1), a cue was presented immediately after having encoded the instructed S-R mappings of the inducer task, which indicated that these mappings would reappear prior to the onset of the probe of the inducer task (double-presentation run) or not (single-presentation run). For single-presentation runs, participants had to prepare for the inducer task in advance by forming S-R associations on the basis of the instructed S-R mappings. In contrast, on double-presentation runs there was no need to do so, because the critical S-R mappings were represented a second time and S-R associations could be formed after the diagnostic task. If instruction-based response activation depends on task preparation, then IB-TRCE should be larger or only present on single-presentation runs.

Method

Participants

Thirty students at Ghent University participated for course requirement or credit. All participants had normal or corrected-to-normal vision and all were naïve to the purpose of the experiment.

Materials

A list of forty-eight stimuli consisted of letters, numbers and symbols. For each participant, a set of 24 pairs of stimuli was randomly constructed on the basis of this list. These pairs were randomly assigned to four blocks. The 6 pairs of each block were randomly assigned to the 6 runs within each block (2 runs with 4 trials of the diagnostic task, 2 runs with 8 trials, and 2 runs with 16 trials). For each run length, one run was a single-presentation run and the other a double-presentation run. Each pair of stimuli was only used for one run. Run length varied randomly so that the probe onset of the inducer task was unpredictable.

In each run, the inducer task and the diagnostic task used the same pair of stimuli and left-right keys (‘A’ and ‘P’ on an AZERTY keyboard). In the inducer task, participants responded to a probe, which was encircled, on the basis of the instructed S-R mappings. In the diagnostic task, participants decided whether a stimulus (presented without a circle) was printed upright or in italic. The left-right response assignment in the diagnostic task was counterbalanced across participants.

On single-presentation runs, the instructed S-R mappings were presented only once at the beginning of each run. On double-presentation runs, these S-R mappings were also presented prior to the onset of the probe of the inducer task. Run type was cued immediately after the initial presentation of the instructed S-R mappings. This was done to ensure that participants still encoded the S-R mappings on the double-presentation runs. The cues consisted of the messages “wordt herhaald” (will be repeated) or “wordt niet herhaald” (will not be repeated) indicating whether the instructions would be repeated or not. Finally, while the initial S-R mappings were always presented in black, the cueing-message and the remainder of the run was presented either in blue or green, with each color indicating whether participants were in a single- or double-presentation run. The color-to-condition assignment was counterbalanced across participants.

Stimuli for both tasks were presented at the center of a white screen in Arial font, size 36. S-R mappings and cue messages were presented in Arial font, size 16. The instructed S-R mappings were randomly presented one above the other in the screen center, such that a mapping referring to a specific response key could be either on the top line or on the bottom line.

Procedure

Participants were tested individually by means of a personal computer with a 17-inch color monitor running Tscope (Stevens, Lammertyn, Verbruggen, & Vandierendonck, 2006). Instructions were presented on screen and paraphrased subsequently. Four blocks of 6 randomly ordered runs were presented with a small break after each block. During each break, feedback was provided about the proportion of errors made on the diagnostic task and the inducer task. Each run started with the presentation of the S-R mappings of the inducer task. These mappings remained on screen until participants pressed the spacebar or a maximum time of 10 seconds elapsed. Once participants pressed the spacebar, a cue was presented for 500ms indicating whether the S-R mappings were repeated or not. The first stimulus of the diagnostic task was presented 500 ms after this cue. Each stimulus in the diagnostic task remained on screen until participants responded or a maximum response time of 2000ms elapsed. Depending on the run length, participants performed 4, 8, or 16 trials of the diagnostic task with an inter-trial interval of 500ms. For single-presentation runs, 500ms after the last response of the diagnostic task, the probe stimulus of the inducer task appeared. For double-presentation runs, 500ms after the last response of the diagnostic task, the instructed S-R mappings of the inducer task were represented. As for the initial presentation, S-R mappings remained on screen until participants pressed the spacebar or 10 seconds elapsed, after which the probe of the inducer task was presented. The probe remained on screen until participants responded or a maximum response time of 2000ms elapsed. A new run started after 1500ms. For incorrect responses the screen turned red for 200ms. The experiment lasted for approximately 30 minutes.

Results

Eight participants who failed to attain 70% of accuracy in the inducer task were considered outliers. The first block was considered practice and not analyzed. Means and standard deviations of all variables in the present study are presented in Table 1.

Diagnostic Task

Only runs on which the inducer task was performed correctly were considered. The first trial of each run was a switch trial and not included. For the RTs only correct trials were included. For each condition and each participant, RTs more than 2 standard deviations above the mean were removed (3.9%). RTs were log-transformed for the analyses. RTs and accuracies were each subjected to a 2 (Congruency) by 2 (Run Type: single- or double-presentation) repeated measures ANOVA. RTs were longer on incongruent trials than on congruent trials, $F(1,21)= 8.82$, $MSE= .001663$, $p<.01$, $\eta_p^2= .30$. The main effect of Run Type was not significant, $F<1$. Both variables interacted, $F(1,21)= 4.35$, $MSE= .001692$, $p<.05$, $\eta_p^2= .17$. For single-presentation runs, RTs on incongruent trials were longer than RTs on congruent trials, $t(21)= 4.14$, $p<.001$, $r^2=.45$. This was not the case for double-presentation runs, $t<1$. For the error rates, the effects of Congruency and Run Type, as well as their interaction were not significant. The largest F-value was observed for Congruency: $F(1,21)= 2.53$, $MSE= .00388$, $p= .127$, $\eta_p^2= .11$.

Inducer Task

Three separate ANOVAs, each with Run Type as a repeated-measures factor, were conducted on the log-transformed encoding times (time between the onset of the S-R mappings and participants' press on the spacebar), log-transformed decision times (time needed for responding to the probe), and decision errors. Encoding times of the first instruction presentation did not vary with Run Type, $F<1$. Decision times were longer for single-presentation runs than for double-presentation runs, $F(1,21)= 160.19$, $MSE= .0148$, $p<.001$, $\eta_p^2= .88$. Less decision errors were made on double-presentation runs than on single-presentation runs, $F(1,21)= 24.10$, $MSE= .006159$, $p<.001$, $\eta_p^2= .53$.

Discussion

An IB-TRCE was present in the diagnostic task for single-presentation runs but not for double-presentation runs. This suggests that on single-presentation runs, participants prepared for the inducer task, which elicited instruction-based response activations in the diagnostic task. For double-presentation runs, participants possibly did not prepare for the inducer task since the instructed S-R mappings of the inducer task were represented prior to the probe onset of the inducer task and no IB-TRCE was observed.

However, the results of the inducer task in Experiment 1 do not offer indications that participants actually prepared more thoroughly for single-presentation runs compared to double-presentation runs. This was prevented by the procedural parameters used in Experiment 1. First, the extent of preparation could not be estimated on the basis of the time to encode the initial instructions, simply because the cue about the repetition of instructions was presented only after the initial instructions were encoded. Hence, there was no reason to assume that initial encoding times would differ between the two types of runs. Second, performance on the inducer task was also uninformative because on double-presentation runs, the S-R mappings were represented immediately prior to the onset of the inducer task. The inducer task was thus much easier on double-presentation runs compared to single-presentation runs. It is thus difficult to conclude that single-presentation runs were associated with more task preparation than the double-presentation runs. Furthermore, participants may have started to prepare for the inducer task on both types of runs immediately after the instructed S-R mappings were presented. The resulting S-R associations could then have been sustained or removed depending on whether a single or double-presentation run was cued. In the latter case, the absence of instruction-based response activation may have been caused by the inhibition of the instructed S-R associations on double-presentation runs. The possible presence of such inhibition on those runs, makes it unclear whether encoding instructed S-R mappings without actually preparing for them, equally does not lead to instruction-based response activations.

Experiment 2

In view of the concerns associated with Experiment 1, Experiment 2 aimed to manipulate the necessity to prepare for the inducer task in a different way (see Figure 1). On each run, participants were cued that they would have to respond to the probe of the inducer task within a 1500ms response window (early-deadline run) or within a 5000ms response window (late-deadline run). The rationale is that participants should prepare for the inducer task on early-deadline runs but not on late-deadline runs (see also, Lien, Ruthruff, Remington, & Johnston, 2005, for a similar logic). As such, S-R associations should be formed in advance for early-deadline runs but not for late-deadline runs and the IB-TRCE should be larger or only present on early-deadline runs. The deadline was now cued simultaneously with the instructed S-R mapping and late-deadline runs did thus not trigger redundant task preparation, as it was the case on double-registration runs in Experiment 1. Moreover, the deadline manipulation allowed us to assess differences in task preparation by comparing performance on the inducer task between early- and late-deadline runs. A potential concern is that performance on the inducer task could be biased by a speed-accuracy trade-off, which is a common finding when using deadline procedures (Wickelgren, 1977). This does not apply for the diagnostic task (and the IB-TRCE) in which the response deadline was not varied and participants had no reason to adopt different speed-accuracy strategies.

Method

Thirty-four participants were recruited from the same pool. None of them participated in Experiment 1. Tasks and materials were the same as in Experiment 1, except for the following changes. First, only single-presentation runs were used. Second, the response deadline to the probe of the inducer task was manipulated. On early-deadline runs, the response deadline was 1500ms, while on late-deadline runs the response deadline was 5000ms. Run type was cued simultaneously with the presentation of the S-R mappings. Participants were cued they had 1 second to respond for early-deadline runs and 5 seconds for late-deadline runs. For early-deadline runs, the instructed deadline was thus shorter than the actual deadline. We did this to minimize the number of late responses while at the same time maximizing the effort that participants would put into preparing the inducer task. Both run types were presented in blue or green, to inform participants about the ruling deadline.

Results

The exclusion criteria and raw-data processing were the same as in Experiment 1, resulting in the exclusion of eight participants.

Diagnostic Task

RTs (3.7% outliers) and accuracies were each subjected to a 2 (Congruency: congruent or incongruent) by 2 (Run Type: early- or late-deadline) repeated measures

ANOVA. RTs were longer on incongruent trials than on congruent trials, $F(1,25)= 6.25$, $MSE= .004059$, $p<.05$, $\eta_p^2= .20$. RTs were shorter on early-deadline runs than on late-deadline runs, $F(1,25)= 6.91$, $MSE= .004196$, $p<.05$, $\eta_p^2= .22$. Both main effects interacted, $F(1,25)= 4.40$, $MSE= .0012375$, $p<.05$, $\eta_p^2= .15$. For early-deadline runs, RTs on incongruent trials were longer than RTs on congruent trials, $t(25)= 3.59$, $p<.01$, $r^2=.34$. This was not the case for late-deadline runs, $t(25)=1.07$, $p= .294$, $r^2=.04$.

For the error rates, the main effect of congruency was significant, $F(1,25)= 5.49$, $MSE= .002123$, $p<.05$, $\eta_p^2= .18$, with less errors on congruent trials compared to incongruent trials. The main effect of Run Type was not significant, $F<1$. The interaction between both main effects did not reach significance for errors, $F(1,25)= 2.03$, $MSE= .004791$, $p= .17$, $\eta_p^2= .07$.

Inducer Task

There was a trend for shorter encoding times for late-deadline runs compared to early-deadline runs, $F(1,25)= 3.26$, $MSE= .027169$, $p= .083$, $\eta_p^2= .12$. Decision times were shorter for early-deadline runs than for late-deadline runs, $F(1,25)= 4.59$, $MSE= .017316$, $p<.05$, $\eta_p^2= .16$. Decision errors did not vary with Run Type, $F(1,25)= 2.62$, $MSE= .010950$, $p= .118$, $\eta_p^2= .09$.

Discussion

The IB-TRCE was present for early-deadline runs but not for late-deadline runs. Performance in the inducer task also differed between both run types. Encoding times were (numerically) shorter on late-deadline runs than on early-deadline runs. Participants thus tended to spend less time processing S-R mappings on late-deadline runs. Decision times on the inducer task were longer for late deadlines than for early deadlines. This pattern of results suggests that participants prepared for the inducer task more thoroughly on early-deadline runs than on late-deadline runs. Experiment 2 thus offers more direct evidence that IB-TRCE depends on task preparation and that simply encoding instructed S-R mappings does not trigger an IB-TRCE.

Nevertheless, a main effect of run type was present, indicating that RTs of the diagnostic task were overall longer on late-deadline runs compared to early-deadline runs. Hence, instruction-based response activations may have started to decay on slow responses (Hommel, 1994) of late-deadline runs. To test this hypothesis, additional analyses were conducted in which response speed was taken into account by performing a median-split on the RTs of the diagnostic task and including response speed as a factor. The interaction between Response Speed and Congruency was not significant, $F(1,25)= 2.42$, $MSE= .0025512$, $p=.133$, $\eta_p^2= .09$. The interaction between Congruency, Run Type, and Response Speed was also not significant, $F(1,25)= 1.16$, $MSE= .0011376$, $p=.291$, $\eta_p^2= .04$. Finally, no IB-TRCE was present on the fastest responses of late-deadline runs, $t(25)=1.05$, $p=.30$, $r^2=.04$. The IB-TRCE thus does not seem to depend on the response speed in the diagnostic task.

General Discussion

The present study tested whether instruction-based response activations depend on task preparation. We manipulated the amount of preparation the inducer task required and measured IB-TRCE in the diagnostic task. IB-TRCE were only present when the S-R mappings of the inducer task were only presented once at the beginning of a run (Experiment 1) and when an early deadline was imposed to the inducer task (Experiment 2). Experiment 2 also indicated different degrees of task preparation in the inducer task between early- and late-deadline runs, strengthening the conclusion that instruction-based response activation depends on task preparation.

The present experiments offer more evidence for the hypothesis that instruction-based response activations and task preparation are strongly related (Liefooghe et al., 2012; Meiran et al., 2012; Wenke et al. 2009), which suggests that instructions-based response activation depend on the active and advance implementation of instructed S-R mappings. Such implementation requires the temporary binding of conceptual codes representing instructed stimuli and responses (Liefooghe et al., 2012; Wenke et al., 2007, 2009), which may be a function of DA in working memory, by connecting stimulus and response representations in ALTM on the basis of task instructions (Meiran et al., 2012). DA is thus involved only before actual responding is required when stringent preparation demands are imposed. When preparatory demands are absent or too lenient, DA is not involved beforehand, but only when the imperative stimulus is presented and the instructed S-R mappings need to be implemented into functional S-R associations in order to produce a response.

Instructed S-R mappings can thus be maintained without being implemented. This can possibly be explained by distinguishing between declarative and procedural working memory (Oberauer, 2009). Declarative working memory holds representations for processing and procedural working memory holds representations that control processing, with each system having separate capacity limits. Previous research (Liefooghe et al., 2012; Wenke et al., 2009) suggested that instructed S-R mappings are maintained in declarative working memory, while implemented S-R associations are represented in procedural working memory, with only the latter type of representation eliciting instruction-based response activations. Alternatively, it is possible that S-R mappings that have not yet been implemented are simply represented in ALTM and that S-R associations are only formed by means of the DA when necessary.

A puzzling finding in this context is that both in Experiments 1 and 2, RTs in the diagnostic task did not increase when (more) preparation was required in the inducer task. This suggests that being prepared for the inducer task, does not elicit a larger load on the diagnostic task. The absence of such load-effect may suggest that maintaining non-implemented S-R mappings in declarative working memory or maintaining implemented S-R associations in procedural working memory delays processing in the diagnostic task to the same extend. Alternatively, it could be that performance in the diagnostic task in itself operates relatively independently of DA. The overly practiced S-R mappings of the diagnostic task may result in the formation of S-R associations in ALTM, which are automatically retrieved when performing the diagnostic task. As such, the presence of additional S-R associations in DA, may only minimally delay processing in the diagnostic task. Clearly, these issues indicate that future research will have to pinpoint the representational differences between implemented and non-implemented S-R mappings.

Taken together, our results are in line with the idea that instruction-based response activations depend on controlled, and likely strategically mediated, processes of advance preparation (Liefooghe et al., 2012; Meiran et al., 2012; Wenke et al., 2009), which result in the formation of S-R associations that automatically trigger responses even when these associations are irrelevant for the current task. The present study thus again suggests that although both instructed and practiced S-R associations lead to automatic response activations, they are represented in a different way in working memory, with instructed S-R associations being more depending on DA activity compared to practiced S-R associations.

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Table 1. Mean results and corresponding standard deviations (between brackets) of Experiments 1 & 2. The size of the instruction-based task-rule congruency effect (IB-TRCE) is also reported. Note that untransformed RTs, Encoding Times, and Decision Times are presented.

Diagnostic Task	Trial Type	Experiment 1		Experiment 2	
		Single Presentation	Double Presentation	Early Deadline	Late Deadline
RTs	Incongruent	563 (56)	551 (54)	599 (78)	608 (60)
	Congruent	539 (58)	547 (50)	571 (67)	599 (72)
	IB-TRCE	*24*	*4*	*28*	*9*
Error Rates	Incongruent	.09 (.05)	.09 (.07)	.08 (.06)	.07 (.04)
	Congruent	.06 (.06)	.07 (.05)	.04 (.04)	.06 (.07)
	IB-TRCE	*.03*	*.02*	*.04*	*.01*
Inducer Task					
	Encoding Times	3822 (2042)	3760 (2118)	5689 (3663)	5177 (2942)
	Decision Times	893 (131)	566 (121)	840 (157)	914 (209)
	Decision Error Rates	.14 (.10)	.02 (.06)	.14 (.14)	.09 (.09)

Figure Captions

Figure 1. Outline of the basic procedure used to measure IB-TRCE and the variants used in Experiments 1 and 2 of the present study.

Figures

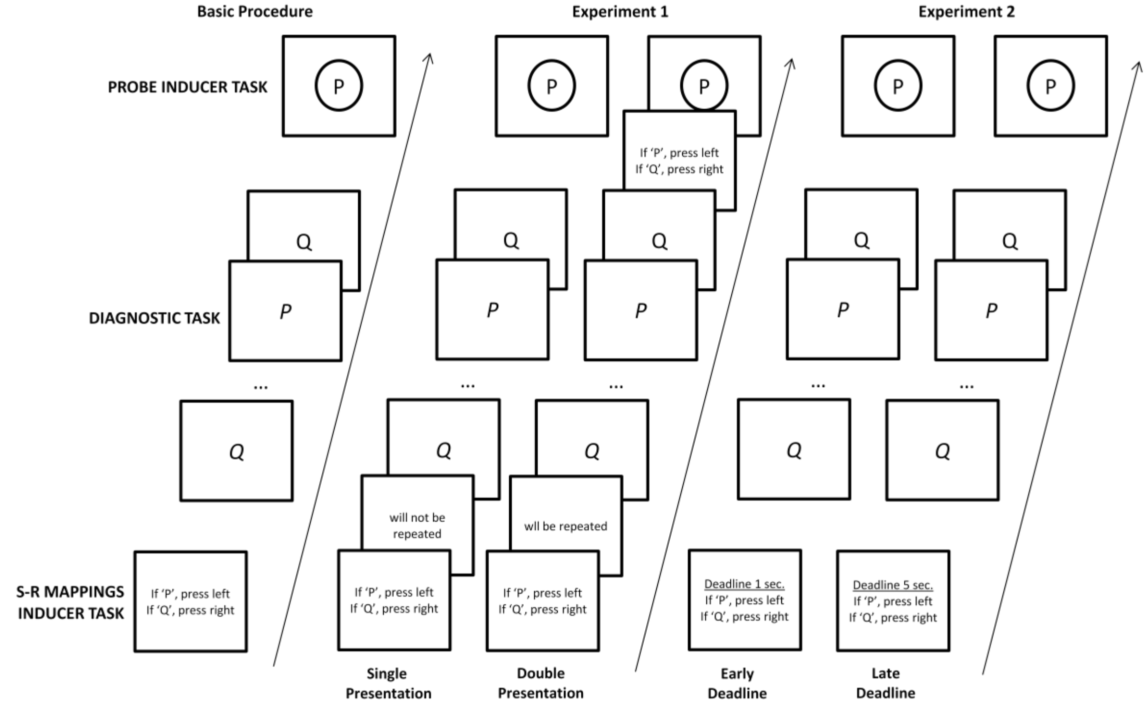

Figure 1